



REPORT OF SURVEY CONDUCTED AT

**SACRAMENTO MANUFACTURING
AND SERVICES DIVISION**

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Best Manufacturing Practices

CENTER OF EXCELLENCE FOR BEST MANUFACTURING PRACTICES
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Foreword



This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective towards this goal is simple: to identify best practices, document them, and then encourage industry and Government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource to help companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to avoid costly and time-consuming duplication of what others have already tried and learned from.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at the Sacramento Manufacturing and Services Division (SMSD) conducted during the week of October 30, 1995. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from government, industry, and academia throughout the U.S. and Canada – *so the knowledge can be shared*. BMP also distributes this information through several interactive services including CD-ROMs, BMPnet, and a World Wide Web HomePage located on Internet at <http://www.bmpcoe.org>. The actual exchange of detailed data is between companies at their discretion.

SMSD is located at the Sacramento Air Logistics Center on McClellan Air Force Base, California and covers 14 acres. Supported by a dedicated workforce, SMSD provides support for fielded aircraft, rapidly responding to needed repairs and upgrades when industry has been unable to do so. In instances with the T-38 and F-117 aircraft, SMSD has not only redesigned components but also the production processes needed to manufacture the parts. These responses were quick *and* successful.

SMSD is an outwardly-focused division of the Air Logistics Center, participating in the new Casting Emission Reduction Program with major automakers to develop and improve materials in foundry technologies while concurrently achieving a zero effect on the environment. This effort is in response to a critical need to maintain the competitive edge for U.S. foundries that provide pivotal support in commercial and defense manufacturing.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on the Sacramento Manufacturing and Services Division expands BMP's contribution toward its goal of a stronger, more competitive, and more globally-minded American industrial program.

I encourage your participation and use of this unique resource.

A handwritten signature in dark ink, appearing to read "Ernie Renner".

Ernie Renner
Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

The Sacramento Manufacturing and Services Division (SMSD) is one of five divisions of the Sacramento Air Logistics Center located on McClellan Air Force Base in Sacramento, California. Covering 14 acres and 7 buildings, personnel from areas such as engineering, computer programming, system administration, environmental management, and manufacturing make up the workforce of the Division. The Sacramento Air Logistics Center (SALC) began operation as the Sacramento Air Depot in 1938 with the transfer of personnel and equipment from the Army's Rockwell Field near San Diego, California. The Center has expanded physically and technologically to keep pace with the rapidly changing rate of aircraft design and development.

SMSD maintains leading-edge capabilities in adapting and applying the latest in advanced technologies and methodologies to continuously improve its operation. There are several branches inside SMSD including the following groups.

- The Manufacturing and Support Branch is responsible for the fabrication of metal parts, repair and modification of sheetmetal structures, surface cleaning, treatment and painting, welding, heat treat, pattern making, foundry and battery servicing support.
- The Advanced Structures and Non-Destructive Inspection (NDI) Inspection Branch remanufactures, repairs, and modifies aircraft bonded honeycomb and advanced composite components. This branch maintains a state-of-the-art NDI facility capable of performing all standard NDI processes. This world-class facility includes two of the largest overhead gantry programmable robots in the world. These are used for inspecting intact aircraft in real time or film; include an exclusive neutron inspection system capable of pinpointing minute amounts of moisture and corrosion inside inaccessible areas throughout the aircraft; a singular neutron inspection robot which generates film for use in identifying moisture and corrosion; and a state-of-the-art TRIGA reactor used on leading edge research projects such as the Silicon Doping project for NASA.
- The Facilities and Technology Support Branch maintains overall responsibility for the long-range equipment and facility requirements for SMSD and manages associated budget accounts.
- The Production Control Branch provides total quality, budget and special projects management for SMSD. It

conducts special studies, quality program oversight, process improvement audits, and is responsible for all depot maintenance management information systems.

Although the SALC is currently slated for closure, SMSD's workforce remains dedicated to the mission of the Center. Ongoing efforts include the installation of a Laser Ultrasonic Inspection System and enhancing the NDI Data Fusion capabilities. SMSD is also pursuing efforts with the Massachusetts Institute of Technology to computer model part anomalies.

Whether providing needed support for fielded aircraft or participating in an aggressive new foundry program with leading automakers and DoD, SMSD personnel continue to provide exceptional service to their customers. A prime example of this commitment is the SMSD Advanced Composite Repair and Manufacture Section's response to an industry shortfall to meet F-117 operational requirements. Because of the inability of the materials to withstand the extreme service temperatures, the components were redesigned by the SMSD, and production processes were successfully modified to manufacture these high-temperature parts. The rapid response took place in *just six months*.

This dedicated effort was echoed in SMSD's similar effort to meet industry's inability to redesign the T-38 windshield canopy frame which sometimes failed during in-flight bird strikes, placing aircraft and pilots at risk. The SMSD assumed the task of designing a new, flexible frame when commercial companies failed to successfully produce one. SMSD not only redesigned the system, but also developed bond tooling concepts, made material selections, and developed the necessary support processes. The resultant frames are now interchangeable from aircraft to aircraft, and are being produced at a zero rejection rate. The redesigned frame with a fiberglass/steel arch has resulted in saving the lives of four pilots to date.

The future of the U.S. foundry capabilities also remains an area of interest for SMSD. Metal castings continue to constitute a crucial element of commercial and defense manufacturing. Consequently, foundries and their products – metal castings – are vital to the Department of Defense (DOD), and are essential to the manufacturing industry. SMSD has teamed with major automakers to establish the Casting Emission Reduction Program to improve and develop materials and processes in foundry technologies. This effort will allow the U.S. casting industry to become more competitive while working to achieve a zero effect on the environment.

SMSD's rapid response and "can-do" attitude is indicative of the support the Sacramento Air Logistics Center has provided for the Department of Defense, commercial companies, and foreign governments for over 50 years. Always rapidly responding to the needs of its DOD customer, SMSD is also looking to new areas where its unique capabilities and personnel talent pool can best benefit the U.S. industrial base. The Best Manufacturing Practices survey team considered the following practices to be among the best in Government and industry.

Best Practices

The BMP survey team identified the following best practices at the SMSD:

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Data Integration in an NDI Facility	5
SMSD maintains an impressive NDI facility comprised of a real-time X-ray System, Ultrasonic Auto Bond Tester System, and a Neutron Ray Inspection System to help predict the remaining useful life for aircraft. Image data is captured to determine structural integrity and serviceability of aircraft components.	
F-117 Trailing Edges	6
The Advanced Composite Repair and Manufacture Section of SMSD rapidly responded to the F-117 Program Office's concerns of an industry shortfall to meet the aircraft's operational requirements of extreme service temperature requirements, shortening the life of these components. The components were redesigned by SMSD, capitalizing on new material development from Wright Patterson AFB Materials Laboratory. SMSD also applied a concurrent engineering approach to redesign the trailing edge for ease of producibility and assembly.	
Neutron Inspection System	6
SMSD's neutron inspection system is the only system of its size in the world. It is capable of detecting moisture and corrosion in aircraft components without disassembling them from the main body of the aircraft.	
Real-Time X-ray System	6
A maneuverable, real-time x-ray system at SMSD improves performance of x-ray inspection of composite materials and provides information not available through other inspection processes.	

Item	Page
T-38 Windshield Frame Manufacturing	7
SMSD designed a new, flexible T-38 canopy frame in response to problems encountered with the inability of the windshield and frames to withstand in-flight bird strikes. The original manufacturer of the canopy assembly was unable to respond to requests to redesign the magnesium composite frame to match a new flexible windshield produced to reduce the likelihood of failure due to bird strikes.	
Virtual Reality Simulation Modeling	7
SMSD models foundry manufacturing processes using two modeling and simulation software packages which dynamically demonstrate facilities layout, equipment, people, and techniques in virtual reality.	
Casting Emission Reduction Program	8
The Casting Emission Reduction Program was established at SMSD to improve and develop materials and processes to enhance the casting industry's competitive posture while working to achieve a zero effect on the environment. SMSD has teamed with Chrysler, General Motors, and Ford through the United States Council for Automotive Research for technology resources in a joint applied research project.	
Composite FASTool™ Program	9
SMSD uses the FASTool™ process to proceed from the soft pattern stage to full production tooling in 30 days or less. FASTool™ is a mold form tooling system that uses low temperature curing composite prepreg face sheets to produce an exact replication off master molds.	
ICAM Five-Axis Cutter	9
SMSD uses an ICAM Honeycomb Core Carver – a CNC, five-axis router capable of cutting, routing and drilling straight and complex shapes with the highest accuracy and reliability in honeycomb core material.	
Magnetic Rubber NDI	10
SMSD uses a magnetic rubber process to detect flaws in inaccessible areas of steel parts.	
Standard NC Process Package	10
A consulting organization developed a system to provide a standardized method for CNC docu-	

Item	Page	Item	Page
mentation when SMSD realized that its existing methods for creating and standardizing NC Machining Process Packages were contributing to a number of associated problems in its manufacturing processes.		technical data package was not available from the contractor.	
Employee Testing and Training Program	11	Eddy Current	15
SMSD's employee testing and training program designed to train employees in those areas specifically required for their jobs, prepares them for ISO 9000 compliance, and also fosters pride and morale.		This technique is being extensively used for the detection of cracks emanating from bolt/rivet holes in aircraft skins. The devices used at SMSD can provide a point measurement capability for scanning one bolt hole at a time with a hand scanner.	
Interactive Marketing	11	Inspection Modeling	15
SMSD's innovative marketing approach uses a interactive CD ROM to reinforce customer's confidence in SMSD's capabilities, update information concerning its capabilities, and increase the quality of individual presentations.		A project has been initiated at SMSD to develop algorithms and models for correlating data acquired from NDI systems with data on strength characteristics and failure modes.	
Quick Reaction Manufacturing	11	Manufacture of Fuselage Station 880-890 Beams for the KC-135 Aircraft	16
SMSD reacts quickly to meet the manufacturing needs of its customers by employing a customer support philosophy that fosters the TQM principles of people empowerment and continuous improvement.		SMSD developed an alternative approach for manufacturing the fuselage station beams for the KC-135 aircraft. Repair of the cracked beams normally required replacement, and from a single source supplier who had historically been costly and required a long lead time.	
Rawstock Requirements Contract	12	Reverse Engineering	16
SMSD developed a more responsive and efficient rawstock provisioning system which resulted in selectively identifying SMSD's anticipated rawstock needs for the coming year, submitting a solicitation, and awarding a multi-year contract to a vendor who acted as a rawstock material broker.		To enhance its reverse engineering capability, SMSD has upgraded its CAD/CAM and machining processes with state-of-the-art technology which has increased its customer support.	
Theory of Constraints in Practice	12	Alternatives to Chrome Plating	16
SMSD has adopted and applied the Goldratt Theory of Constraints, a systems approach to management which focuses improvement efforts on a system's weak link or core problem.		SMSD is currently evaluating two substitutes for traditional chrome plating to determine whether they can be qualified replacements in response to EPA legislation requiring disposal of waste materials and phase-out of chromate use.	
Information		Chaff Flare Box Injection Molding	17
The following information items were highlighted at SMSD.		SMSD re-engineered a chaff flare box in response to an aircraft operational problem that private contractors were unable to correct. The result was a replacement with significant cost savings, lighter in weight, easier to install and maintain, with fewer parts, and generally performs better when compared to the original unit.	
Item	Page	Environmental Issues	17
Amphibious Assault Vehicle Technical Data Package	15	SMSD has taken a proactive leadership role in the area of environmental improvements and compliance.	
The Marine Corps solicited help from the SMSD to have the transmission castings for its amphibious assault vehicle reverse engineered because the			

Item	Page	Item	Page
High Velocity Oxygen Fuel	17	Shop Floor Parts Tracking System Overview	19
SMSD is procuring Jet High Velocity Oxygen Fuel equipment for high kinetic energy and controlled BTU output to produce dense, very low porosity coatings.		SMSD is organizing a Shop Floor Parts Tracking System to report status and statistics on parts, kits, subassemblies, and assemblies in inventory as they are processed on the shop floor. This system will be the cornerstone of a future paperless automated agile manufacturing environment.	
Laser Reverse Machining	18	Ultrasonic Inspections	20
SMSD is installing a Laser Reverse Machining cell to enhance its ability to perform depot-level repair of worn or damaged aircraft metallic parts. The new laser cell will provide the central process for more accurate cutting and higher precision application of the cladding material.		Ultrasonic testing, extensively used to detect internal defects in structures, has a longstanding history of successful inspection at SMSD of both metallic and composite aircraft components.	
Magnetic Particle and Penetrant	18	Vacuum Welding Chamber	21
Portable and stationary magnetic particle and dye penetrant testing are performed at SMSD to detect both surface breaking cracks and subsurface cracks.		SMSD is completing installation of a vacuum welding chamber for welding titanium components. The system will be operational in early 1996.	
No-Bake Sand System	18	Water Jet Cutting	21
A no-bake sand system is being installed in the foundry at SMSD to replace the typical aluminum sand casting operation in which the core is baked to remove excess gases. Instead of manually mixing the sand, binder, and catalyst, packing it into a mold, placing the core into the mold, and pouring molten meal inside, the No-Bake Sand System offers automated mold making that requires no baking.		SMSD recently installed an abrasive water jet cutter for added versatility in its machining operations. This system helps SMSD to economically manufacture products and process materials that normally cannot be processed by conventional machining methods.	
Plating Shop Rehabilitation	18	Community Involvement	21
SMSD is renovating its outdated plating shop while maintaining daily operations. An FY94 Military Construction Project funded for \$17.9M is being used to renovate the facility and bring it into compliance with all current environmental requirements.		The employees of Sacramento Air Logistics Center, of which SMSD is part, are active in community involvement programs. These programs range from charity donations to blood drives, to school involvement, and recycling efforts.	
Robotic Painter System	19	ISO 9000 Implementation Approach	21
SMSD maintains a large parts painting capability housed in a 20 foot wide by 16 feet high by 20 feet deep paint dryer and booth equipped with a six-axis Robotic Painter System.		SMSD is developing a quality assurance plan on a current production program that will serve as a prototype blueprint for incorporating Air Force programs into the ISO 9000 structure.	
Set-up Reduction Project	19	Activity Point of Contact	
SMSD has developed a program to reduce the cost of machining in a job shop environment by applying Single Minute Exchange of Dies to perform all machine set-ups in 10 minutes or less.		For information on any item in this report, please contact:	
		Mr. Doyle Ables Planning Chairman, Manufacturing Support Unit Technology and Industrial Support Directorate SM-AFC/TIMMO 5201 Bailey Loop McClellan AFB, CA 95652-2614 (916) 643-6085 FAX: (916) 643-4419	

Section 2

Best Practices

Design/Test

Data Integration in an NDI Facility

The SMSD NDI facility was established to perform non-destructive inspection of intact aircraft, aircraft components, and other items requiring inspection such as antenna components and structural members. The items are inspected for flaws, anomalies, defects, corrosion, FOD, FOD damage and repair areas. The inspection data on a particular item is electronically captured as images, wave forms, and other data. The data is then converted to a simple visual format and delivered with the item to the repair shop. Until recently these individual, independent inspections have been analyzed separately with no electronic connection between the systems. Joint CALS technology and numerous networked high-powered computers have enabled overlaying the data between the SMSD inspection systems.

Inspectors cannot always determine the nature of a defect from a single NDI inspection. However, using the integrated systems, SMSD operators can visually overlay the Laser Ultrasonic inspection, x-ray inspection, neutron-ray (n-ray) inspection, and other more traditional inspections. This allows the inspector to stack the inspection images for analysis of an item. Overlaying inspections greatly enhance the inspector's ability to accurately determine a defect's nature. Joint CALS technology and the SMSD NDI network of inspection systems facilitate inspection data analysis using data from multiple inspection systems from any workstation within the NDI network. SMSD maintains that these systems can be used to begin predicting the remaining useful life for aircraft and aircraft components.

At the SMSD NDI facility, inspection data is obtained from a Real-time X-ray System, Ultrasonic Auto Bond Tester System, and the N-ray Inspection System. Testing systems and users housed in three buildings are integrated by a fiber optic network and an Oracle database running on a DEC file server. Image records in the central database contain aircraft type, model, prefix, part name and number, nomenclature,

inspection operator identifier, time and date of inspection, original and enhanced images, enhancement algorithm used, defect x-y coordinates, type of defect, and textual comments on the image. Users can retrieve inspection data from the database based on a number of keys and may select from one of several image viewing software tools. The software packages allow the user to overlay and view inspection images from different sources.

The data integration effort is a three-phase activity. Phase I was completed in April 1995 and is currently used to develop baseline reference data for a number of different types of aircraft. The current system provides an improvement over previous manual techniques based on film methods since data is collected in real-time, is network accessible, and over-layable from multiple inspection sources. Phase II and III activities integrate additional inspection data sources such as laser ultrasonic inspection, upgraded computer hardware, and enhanced data fusion capabilities for integrating analysis and viewing inspection data (Figure 2-1).

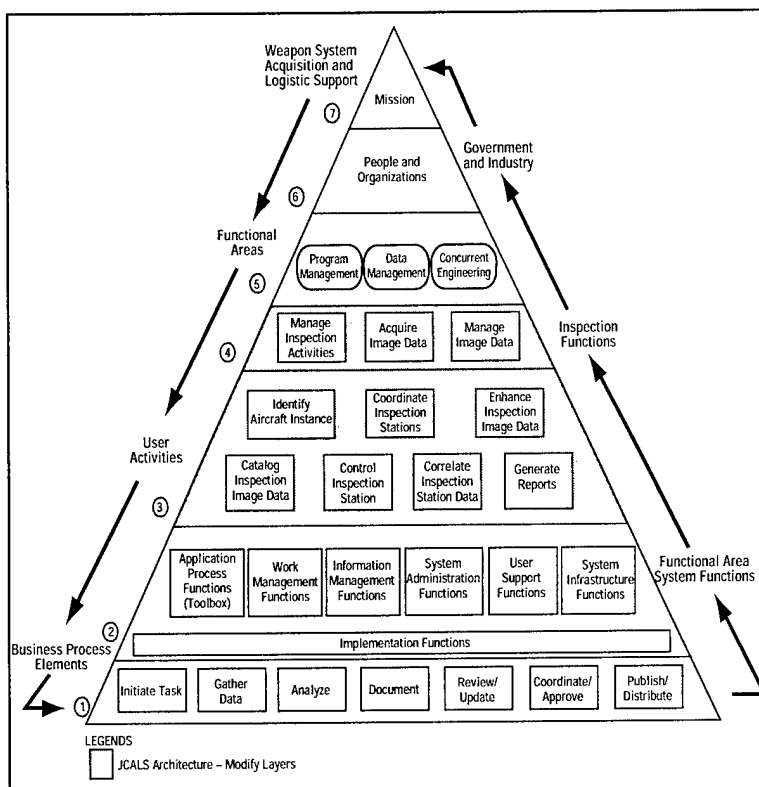


Figure 2-1. NDI Facility Functional Architecture

F-117 Trailing Edges

The Advanced Composite Repair and Manufacture Section of SMSD rapidly responded to the F-117 Program Office's concerns of an industry shortfall to meet the aircraft's operational requirements. The original trailing edges for the F-117 were manufactured by Lockheed from materials that were not able to withstand the extreme service temperature requirement of 750° F. As a result, the life of these components was severely limited.

As an off-the-shelf high temperature material system was not readily available to the aircraft industry, the components were redesigned by SMSD, capitalizing on new material development from the Wright Patterson AFB Materials Laboratory. The new composite material, AFR 700, accommodated full operation of the components in the extreme temperature environment. As a result of this effort, two material vendors, SP Systems of Los Angeles, CA and Hexcel of Livermore, CA have been approved as material suppliers for the new material system.

In addition to the new material system, SMSD applied a concurrent engineering approach to redesign the trailing edge for ease of producibility and assembly. The design effort reduced part count fivefold, resulting in a single piece skin. Part weight was also reduced by approximately 75-100 pounds per aircraft resulting in greater payload, increased specific fuel consumption, and fly-away cost savings.

Production processes had to be modified to successfully manufacture these high temperature parts. Tooling changes included the use of stainless steel bond tools with capton coating to alleviate corrosion. Autoclave processing of these components required high cure cycle temperatures and pressures for long durations (200 psi, 750° F, 36-hour cure cycle) which drove changes such as stainless steel fixturing and rigging, redesigned door seal rings, chilling features, and vacuum pump alterations.

SMSD's rapid response resulted in the successful manufacture of prototype parts in only six months, illustrating in-house expertise from prototype design and development through transition to production. SMSD is now halfway through its initial production run with approximately 120 of the trailing edge parts successfully delivered to the F-117 Depot, and an additional order for 15 more ship sets. The manufacturing cost of the trailing edge components was reduced from approximately \$48K to \$35K, with the additional benefits of extended service life and weight reduction.

Neutron Inspection System

A key capability of the SMSD's unique NDI facility is provided by the N-ray inspection system. Built around a TRIGA nuclear reactor, the system can detect moisture and corrosion in aircraft components without disassembling

them from the aircraft's main body. This system is the only one of its size in the world, capable of scanning an entire aircraft.

The N-ray system consists of a hangar-enclosed gantry robot with a work envelope of 84 feet wide by 85 feet deep by 25 feet high. The six-axis robot is capable of moving the neutron source (Californium) along a pre-programmed inspection path to inspect the entire aircraft once it is positioned in the hanger. This method of inspection is capable of detecting moisture in areas where normal inspection methods would fail without extensive disassembly such as in a wing core cell.

The inspector controls the operation from a remote control station and can stop the inspection process at any time to perform specific functions such as zoom and search of a selected location. If interrupted, the system is capable of picking up the previous inspection point within 0.025-inch. The detectors have a nine-inch diameter field of view with a one-inch overlap which ensures complete coverage of areas under inspection. Inspection of the underside of the aircraft is accomplished by the use of a separate neutron source using a track-mounted fixture that passes under the aircraft along a fixed track. In real-time operation, all information is recorded on Beta videotape for archiving and later analysis.

The facility is continually adding more model information to its database and is currently scheduled to perform similar inspection work for the Canadian Air Force.

Real-Time X-ray System

Another critical element of SMSD's NDI facility is a maneuverable, real-time x-ray system which improves the performance of x-ray inspection of composite materials on assembled aircraft while providing information not available from other inspection processes. The system supports real-time x-ray aircraft inspection using a robot-mounted system. This unique system is 77 feet wide by 90 feet deep and 25 feet high, and has 420 KV and 160 KV x-ray systems mounted on a large gantry robot which is installed in a specially-constructed, shielded aircraft hangar. It is the only facility of its kind in the world.

X-ray inspection technology is used to check wings and other structural components for fatigue cracks, internal damage to hinges, and frame members. Bonded honeycomb components are checked for core damage and water/corrosion. Outputs from this x-ray inspection system include structural and bonded integrity-defect data, photo-videotape graph recorded data, corrosion-moisture detection and location, and crack-debond detection and location.

Benefits obtained from this process include enhanced system speed, increased resolution, defects documentation, and flexibility.

T-38 Windshield Frame Manufacturing

SMDS designed a new, flexible-frame T-38 canopy frame in response to problems with the inability of the windshield and frames to withstand in-flight bird strikes. The frame and windshield were too rigid and would break on impact even when the birds weighed as little as four pounds and impacted at speeds of 200 knots. Pittsburgh Plate Glass redesigned the canopy to incorporate additional flexibility. However, the original canopy assembly contractors were unable to respond to requests to redesign the magnesium composite canopy frame to match the new flexible windshield.

To resolve this problem, SMDS took on the responsibility to redesign the system. It also developed bond tooling concepts, made material selections, and developed processes for pattern cutting, ply lay-up, vacuum bagging materials, debulking, curing, trimming, and dimensional measuring. Additionally, a tracking system was implemented to capture all pertinent manufacturing data from identification of raw materials to final serialization of each

frame assembly. The resultant frames are now interchangeable from aircraft to aircraft, have an amortized cost of approximately \$60K each, and are being produced at a zero rejection rate.

The redesign was a composite frame with a fiberglass/steel arch consisting of four parts assembled in a fixture and cured in an autoclave using the recently developed FASTool™ mold system. This frame was submitted to Wright-Patterson AFB for testing and passed a four-pound, 400-knot bird strike test.

The SMDS Advanced Composite Section is now the only facility manufacturing the T-38 windshield frames. In production since mid-1993, SMDS has produced approximately 230 frame assemblies with a current production rate of 25 frames per month. SMDS is currently developing prototypes for the F-5 aircraft windshield canopy and is pursuing increased Foreign Military Sales by promoting this recent manufacturing advance. Bird strikes on aircraft with the new windshield canopy frame resulted in saving the lives of four pilots and avoiding the loss of all four aircraft. This technology is transportable to other aircraft in service that do not currently meet more stringent bird-strike requirements.

Virtual Reality Simulation Modeling

Foundry manufacturing processes are rapidly modelled at SMDS using Queuing Event Simulation Tool (QUEST) and Interactive Graphic Robotic Instruction Programming (IGRIP) software. Using these modeling and simulation software packages allows the dynamic demonstration of facilities layout, equipment, people, and techniques in virtual reality (VR) (Figure 2-2). The conventional method of manufacturing design and demonstration was through traditional two-dimensional modeling which required labor-intensive simulation efforts. Analysis of key characteristics were time consuming, costly, required specialized skills, lacked accuracy in what-if scenarios, and were usually difficult to communicate.

The VR simulation tool analyzes industrial and support processes through QUEST software (discrete simulation for manufacturing systems); and IGRIP software (continuous simulation for detailed work task, work cell, energy expenditure, and ergonomics analyses). This type of demonstration technique effectively helps

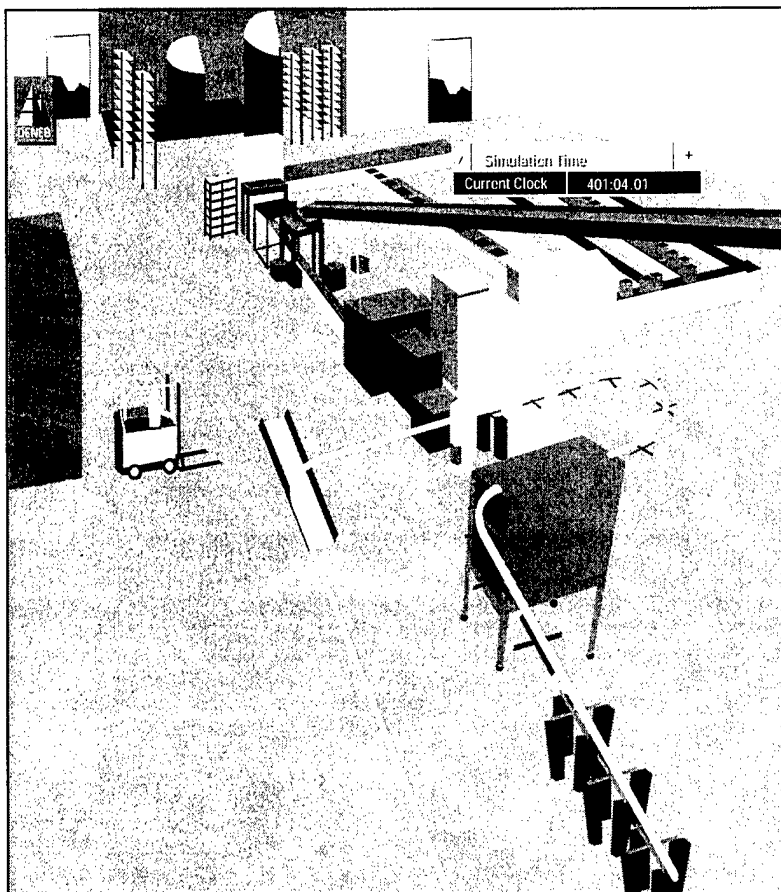


Figure 2-2. Casting Simulation

users manage and analyze the manufacturing design and production processes. Equipment throughput, bottlenecks, work flows, operations, and operator ergonomics are quantified for evaluation. The VR interface provides three-dimensional viewing of processes with Crystal Eyes™ and high-end graphics. It supports options of fake-space booms, helmets, and immersion within a VR cave.

This simulation software is currently used on a large, new-start manufacturing process – the Casting Emission Reduction Program's (CERP's) 60,000-square foot foundry. SMSD has quantified the foundry conceptual design and continues to run concurrent simulations as the final design is developed.

SMSD maintains that because of the more realistic viewing provided as the user interface, VR simulation is superior to other methods of quantifying a process, and applications of this new capability are almost limitless. The use of VR simulation modeling will optimize work tasks and work cells, identify and accomplish training before systems are developed, avoid potential repetitive motion injuries to operators, identify material handling requirements, allow what-if scenarios without costly modifications, and help corporate decision-making process.

Production/Facilities

Casting Emission Reduction Program

The Casting Emission Reduction Program (CERP) was established at SMSD to improve and/or develop materials and processes in foundry technologies to enhance the casting industry's competitive posture while working to achieve a zero effect on the environment. SMSD teamed with Chrysler, General Motors, and Ford through the United States Council for Automotive Research for technology resources in a joint applied research project.

CERP is a five-year, \$50M, Congressionally-appropriated program funded through the Advanced Research Project Agency. Steering committee members include the American Foundrymen's Society, the EPA, and the California EPA. Other program participants are the U.S. Casting Suppliers, national laboratories, and universities.

The program established four major milestones as part of its effort including conducting national source testing and developing an emissions baseline for the metal casting industry; install-

ing a fully instrumented, state-of-the-art pilot foundry at McClellan AFB; developing new instrumentation for emission measurement with American Industry/Government Emissions Research; and, developing models for metal casting emissions. The end product will be the development of alternative materials, chemistries, and processes, and the evaluation of cast product attributes.

CERP has already accomplished conditions in each of the several milestone areas.

Milestone 1. The foundry air emissions test program targets 22 foundries across the U.S. to be sampled in an 18-month time frame. This cross-section represents foundries of automotive manufacturers, suppliers, and the DOD. This data will baseline the industry and form the basis of the EPA MACT standards.

Milestone 2. The pilot facility will be a 60,000 square foot casting plant, focusing primarily on gray iron, ductile iron, and aluminum. The product will be a green sand mold process, producing cast iron 4-cylinder engine blocks and the rate of 50 blocks per hour for 2 hours. The facility will be fully operational by fall of 1996.

Milestone 3. For each step in the manufacturing process to be fully monitored to measure all emissions, a \$2M low-level emissions measurement equipment and instrumentation design project has been initiated. This is "next generation" measurement equipment that is required due to the anticipated lowering of current emission levels.

Milestone 4. Computer modeling of casting emissions (Figure 2-3) will include such tasks as finite element analysis. Computer modeling will result in incorporating data from casting and emission studies into actual

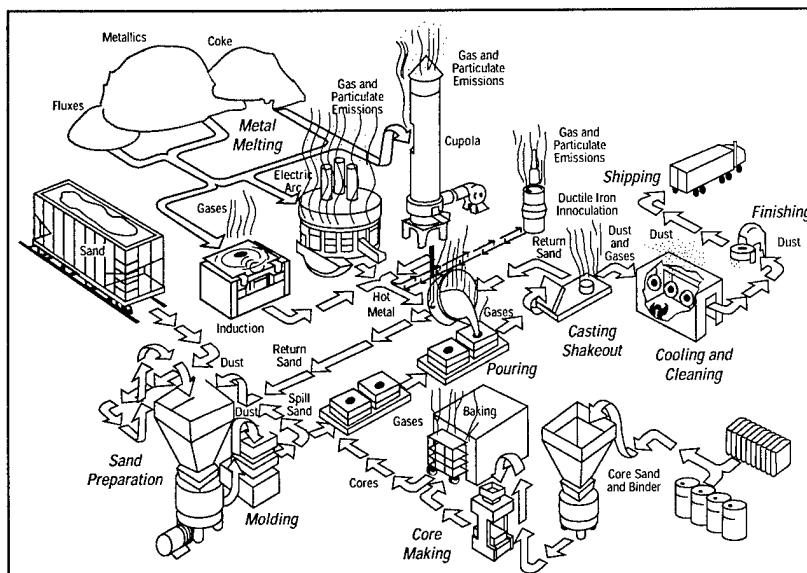


Figure 2-3. Iron Foundry Process

engineering design package for evaluation of environmental effects.

Although the CERP addresses primarily military needs, there are also significant domestic benefits. Maintaining the national foundry industrial base into the next century and establishing new operating parameters and equipment are prime examples of CERP's advantages. SMSD has demonstrated progressive initiative in creating a partnership with DOD, EPA, the Foundrymen's Society, and the Chrysler, General Motors, and Ford automakers to address this difficult task. At the end of this project, production and environmental issues, as well as the assurance of a strong industrial base, will have been addressed.

Composite FASTool™ Program

SMSD uses the FASTool™ process to proceed from the soft pattern stage to full production tooling in 30 days or less (Figure 2-4). FASTool™ is a mold form tooling system that uses low temperature curing composite prepreg face sheets to produce an exact replica off master molds. The composite prepreg face sheets that produce the replica off the master is then reinforced with a ceramic bead/resin mixture that forms a back-up structure. The ceramic bead layer is then covered by another layer of prepreg to complete the mold form assembly, replacing the intricate egg-crate back-up structure previously required. Production molds can withstand a working environment up to 350° F and pressures in excess of 100 psi for 350-400 autoclave cycles.

Traditional methods in bond tooling production included manufacturing metal bond forms in pattern shops. This process consisted of casting soft patterns and fabricating templates, leading to final hard metal tools. This effort was a time-consuming and labor-intensive process that required long lead times of between four and six months before

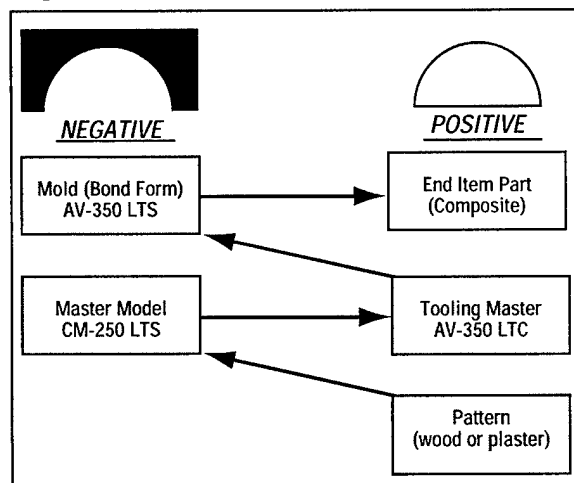


Figure 2-4. FASTool™ Process

actual part production could begin. These traditional tools were manufactured using aluminum or kersite. The coefficients of thermal expansion varied greatly between these materials and materials used for parts production. These coefficient differences resulted in problems accurately reproducing the contours and tolerances required for advanced composite structural components. This traditional method did not allow SMSD to respond rapidly to urgent customer requests for the manufacture of mission critical components.

Exact replication of complex molds using the FASTool™ process has been reduced from months to weeks. SMSD has been able to reduce the turnaround time for new or replacement molds by 40-50%; localize the mold manufacturing process to one specific area within the plant; reduce direct labor from 30 to 5 employees; establish an excellent working relationship with the material vendor, resulting in rapid response to material purchase orders and problem resolution; and reduce the learning curve for mold production versus that of traditional hard metal tooling. This change has allowed SMSD to respond quickly to customer requests for mission critical manufacturing services.

ICAM Five-Axis Cutter

Since 1994, SMSD has used an ICAM Honeycomb Core Carver which is a CNC, five-axis router capable of cutting, routing or drilling straight and complex shapes with the highest accuracy and reliability. Previously, SMSD applied common industry practices for honeycomb and foam core carving by using portable cutting tables and platform routers. To improve quality increase production, SMSD purchased a three-axis honeycomb profiler; however, the equipment was not effective, and did not meet the needs of the shop or the requirements of the customer. The ICAM machine was retrofitted by DeVlieg-Bullard who rebuilt the machine and added two more axis of travel. This made the machine a full, five-axis machining center capable of producing complex shapes and maintaining precise tolerances.

Before use of the ICAM, most core requirements were bought directly from material suppliers in a preshaped but oversized condition. SMSD then performed hand fit and trim operations to fit each piece. Complex shapes and short schedules prohibited industry from providing limited-quantity production runs of the shapes and sizes required for DOD retrofit and repair.

The ICAM allows both sides of the core to be carved to successfully manufacture even the most complex geometries. Utilizing the Binary Cutter Location computer programming network which allows like machine tools to "talk" to one another, complex programs are downloaded from direct numerical programming (or any design database) and are accessed through the use of SMSD's Allen-Bradley 9/260

CNC controller. With the latest DeVlieg-Bullard retrofit to the equipment, even some of the most complex components are successfully formed by the ICAM. The ICAM can accommodate very large parts, with a work envelope up to 23 feet by 9 feet. In addition to the equipment retrofit, DeVlieg-Bullard also trained machine operators and programmers who can fully support this equipment in-house at SMSD.

SMSD has successfully produced complex geometry honeycomb carving on the F-111 horizontal stabilizers. A team of experts, including manufacturing engineering, tooling, and CNC programming are always available to rapidly respond to current and future complex geometry core carving requirements.

Magnetic Rubber NDI

SMSD uses a variety of NDI inspections methods to accomplish many inspections and certifications; one of the most reliable tests used to detect flaws on ferrous parts is magnetic rubber. A derivative of the basic magnetic particle process used in NDI, magnetic rubber was developed by General Dynamics in the early days of the F-111 production. SMSD has used it since the early 1970s as the standard steel inspection method for detecting flaws in inaccessible areas of the part.

Magnetic rubber consists of iron particles suspended in a liquefied silicone rubber. A curing agent is added just prior to its application on the area of the part to be inspected. After applying the rubber, the part is magnetized causing the iron particles to migrate to the surface defects, outlining their size, shape and location. The process is capable of detecting surface flaws smaller than 0.020-inch in length. It can also reproduce the actual surface for a high quality evaluation of the surface finish, scratches, tool marks, or other abnormalities that could evolve as stress areas in future fatigue cracking. After the normal 10-minute cure cycle, the resulting mold is removed from the part and inspected under a 7X to 30X microscope to determine if there are any surface defects that require repairs or replacement of the part.

Using magnetic rubber in the NDI process provides capabilities to inaccessible areas where conventional magnetic particle NDI cannot be used. Areas such as holes and voids – as well as complex shapes and areas having limited visibility – are easily inspected using this method. Like other forms of NDI, magnetic rubber is highly portable and can be used extensively in the field in support of maintenance activities requiring piece part inspection.

Standard NC Process Package

In 1993, SMSD realized that its existing methods for creating and standardizing NC Machining Process Pack-

ages were contributing to a number of associated problems in its manufacturing processes. Consequently, a consulting organization developed a system to provide a standardized method for CNC documentation.

Insufficient and non-standard CNC documentation previously necessitated the on-site presence of the CNC programmer before a machinist could perform the machine setup. This contributed to excessive time and labor charges for machine setup and prevented the programmer from working on other programming tasks. Methods used for the setup and the sequence of the machine cuts frequently resulted in conflicts between the programmer and machinist. Future production orders virtually necessitated a reprogramming of earlier efforts since the processes, tooling, and methods had not been preserved through adequate documentation. These and other problems clearly presented the opportunity for making substantial improvements in the documentation of CNC process packages.

Management recognized the need for outside help in resolving the existing situation. While structuring this new system, the contractor was directed to utilize best techniques and practices of Department of Defense Airframe Manufacturing Prime Contractors, as well as achieving compatibility with the Air Force Logistics Command's EIA 494 Programming Directive. Additionally, the contractor was to maintain an "open door" toward other CNC Standards being recommended by organizations such as the American Society of Manufacturing Engineers, Cincinnati-Milacron In Process Quality Assurance, PDES-STEP ISO/CD 10203-213, and the X3J7 APT.

Working with management, the machinists, and programming staff, the contractor has established a cooperative and effective working relationship, largely the result of a Planning Agreement signed by the Machine Shop Management and the Programming Organization. This agreement clearly states the common goals, objectives, and spirit of cooperation inherently needed for the task. Having a common charter laid the foundation for mutual respect and creative thinking by all stakeholders, resulting in an improved standard documentation system – a system enthusiastically supported by all involved personnel.

The system prescribes a template for accomplishing the detail planning and programming associated with the CNC machine setup and machining processes. It defines and records all the required cutting tools (common and unique), tool offsets, tool holders, required holding fixtures, sequence of performing the machining, and several other pieces of information critical and essential for specifying the setup and machining processes. Also, the system necessitates the close cooperation of the machinist and programmer in the total planning of the task to ensure all aspects of the job are considered for efficient technical execution.

There are several benefits of SMSD's new CNC Standard Documentation. The up-front teamwork and detail planning to optimize the manufacturing processes before production is initiated introduce many efficiencies. The system provides a ready, reusable file when a customer requests manufacturing of the item, reducing the lead time to begin new production and reducing the costs associated with CNC programming and setup. The system offers the customer an alternative source for rapid response manufacturing, considered potentially critical to sustainment of the nation's warfighting capability. The system records can assist commercial organizations in preparing bids and in early delivery of critically needed parts by reducing the lead time to production. The SMSD maintains the real key to resolving the problems was in the strategy taken by management to create a "win-win" environment for all stakeholders.

Logistics/Management

Employee Testing and Training Program

SMSD has implemented an employee testing and training program for the Division which identifies employee training needs using an innovative testing program. It is designed to train employees in those areas specifically required for their jobs, prepares them for ISO 9000 compliance, and also fosters pride and morale. The program has been in operation since 1992. Prior to that time, training received little emphasis and was largely ineffective. Supervisors sent employees to training during slack work times or to fill empty class spaces without regard for individual training requirements. Many of the classes were not related to an employee's specific job. No formal training programs or established skills standards were available.

The employee training and testing program was established to ensure that employees have the knowledge required for their respective job series classifications. It was also intended to give employees the ability to compete for workload, improve morale, and instill pride in quality of workmanship. The program is based on the Air Force Occupational Templates which provide the knowledge and skill requirements for each job classification. Tests are developed by subject matter experts on each of the subjects listed in the AFMC Occupational Templates. Employees are scheduled to take tests required for their specific job series, and are given credit for full qualification in the subjects for which they receive a passing grade. A training matrix has been developed to show training requirements based on test results. Employees are scheduled for training based on individual needs, priorities, and work schedules.

The process was developed in consultation with the union which supports the concept and helps facilitate its imple-

mentation. SMSD has seen positive effects from this program and acknowledges the need to do the training assessment and training program as early as possible in an employee's career. Other lessons learned include establishing a policy to identify training needs at the time of employment and the importance of considering employee training in long-range plans.

Over 70% of the division has completed the training program, producing a significantly improved and effective work force. Employees are now trained only on subjects they need to conserve time and resources. Employees also have greater confidence in their ability to perform their jobs. Productivity and morale have improved markedly and employees now have more options and feel better prepared to face the uncertainties of base closure and privatization.

Interactive Marketing

The SMSD has developed a CD ROM interactive disk for use as an innovative marketing approach. SMSD previously relied on typical marketing techniques such as brochures, customer site visits, videotapes, news articles, and facility tours to disseminate information on its capabilities and services. Although these approaches were successful, SMSD decided to more aggressively increase its market penetration. The CD ROM approach is used to reinforce customer's confidence in SMSD's capabilities, update information concerning its capabilities, and increase the quality of individual presentations.

The marketing CD is a user-friendly, multimedia computer presentation which displays SMSD capabilities. The interactive presentation includes pictures, video, text, and dialogue. A potential customer can view the entire CD or only the portions of interest. It is useful for trade shows and personal presentations where any SMSD representative can present the CD to a potential customer. The excellent use of pictures and full-motion video give the potential customer a clearer understanding of SMSD capabilities over the typical marketing approaches. The CD is compatible with both PC-based and MAC-based computers using a Windows format.

The CD ROM format presents a flexible, professional, high-technology display that has been successful for the SMSD. Development costs for the CD ROM are estimated at \$12K with individual disks at \$4 each. SMSD has been using this approach since 1994 and is now distributing a second version. Future activity includes placing this information on the Internet.

Quick Reaction Manufacturing

SMSD reacts quickly to meet the manufacturing needs of its customers by employing a customer support philosophy

that fosters the TQM principles of people empowerment and continuous improvement.

The standard shop practice at SMSD did not support an environment for the shop worker to take ownership of his work. Process improvements at this level were traditionally not encouraged. The company business and customer interaction were not responsibilities or concerns of the shop worker. As the normally guaranteed workload decreased as a result of DOD downsizing, SMSD established new manufacturing work, but it required quick reaction to meet customer needs. Management recognized that these new work opportunities could not be accomplished without a more active involvement of the shop worker, which led to SMSD's application of people empowerment and continuous improvement.

An example of this new philosophy is provided by a customer with a pressing requirement for 1200 F-18 access doors. SMSD quoted for all the parts to be delivered in 180 days. The customer notified SMSD of a 90-day delivery requirement. SMSD management took the problem to the sheetmetal manufacturing shop workers to develop a plan to accommodate the customer's needs. Management provided full support to the shop workers to meet the task by making available any material required, authority to make process improvements and tool design changes. SMSD was awarded the contract based on price and delivery in 90 days. During the manufacturing process, the shop team perfected tooling that made four parts at a time. Using this new tooling, SMSD reduced the total manufacturing cost and delivered all 1200 parts in 45 days, with \$30K returned to the customer.

The TQM principles of people empowerment and continuous improvement are important reasons for quick reaction manufacturing's success. Customer focus by shop personnel has increased and morale has improved. Repeat work from customers and the development of a new customer base are increasing. This type of work has increased from a little under \$1M in sales for 1994 to \$2.5M in 1995, with projections of \$5M in 1996.

Rawstock Requirements Contract

SMSD developed a more responsive and efficient rawstock provisioning system which resulted in selectively identifying SMSD's anticipated rawstock needs for the coming year, submitting a solicitation, and awarding a multi-year contract to a vendor who acted as a rawstock material broker. This program was needed in response to difficulties procuring rawstock material from organizations outside SMSD. There were long lead times of 90 to 180 days for many common material items such as aluminum and steel alloy plate and bar stock. Materials which did not have a Government national stock number assigned required a

separate contracting action by the Air Logistics Center's Contracting Office. At times, the manufacturing order required a small quantity of raw stock, but the source would not issue material in anything less than the full unit of issue or in minimum lot sizes. This excess stock after the production run created a storage problem, since this material usually could not be returned to government stock.

A review of several alternatives was made through a joint effort with SMSD staff representatives and representatives of the base supply and contracting office. This resulted in the current innovative method which satisfies all affected parties and is in compliance with Federal Acquisition Regulations. Under the contract, as an actual material requirement is identified, SMSD places an order for the exact quantity of material needed. If desired, the division can further specify that the material be precut to precise dimensional specifications. The material broker locates the material, purchases it, has the material precut (if specified), and ships it directly to SMSD. A certification of the material's identity and specifications accompanies the material at the time of receipt.

This system has been operational since 1993 and has proven to be extremely effective in resolving the original problems. For example, the lead time for obtaining common material rawstock has been reduced on the average from two months to seven days, and frequently material is received in three days. Lead time on more uncommon material such as forged aluminum billets has been reduced from one year to sixty days. Precutting the material by the vendor to the premachined length often saves up to one manhour per item since the machine shop does not have to perform this task. Residual material at the end of the production run is virtually eliminated because only the amount needed for the job is procured. Storing excess stock or trying to return the stock back into the base supply system is no longer a problem. All of these improvements translate into reduced costs and a lower price to the customer. However, the single most important benefit of this improved material ordering system is meeting the customer's expectation for delivery of finished goods. Previously, delivery dates could not be accurately forecasted and when promised dates were not met, the customer lost confidence in the Division as a preferred source of manufacture. Satisfying and exceeding the customer's expectations for quality, cost, and timely delivery assures future placement of manufacturing orders for the Division.

Theory of Constraint in Practice

Since 1993, SMSD has adopted and applied the Goldratt Theory of Constraints (TOC), a systems approach to management which focuses improvement efforts on a system's weak link or core problem. It complements TQM practices

by focusing quality efforts and provides a set of problem-solving tools to logically and systematically answer the questions essential to the process of ongoing improvement – what to change (the problem), what to change to (the solution), and how to cause the change (the implementation plan).

Prior to adopting TOC, SMSD typically used a shotgun approach to improvement efforts, producing little buy-in by stakeholders and resulting in sub-optimization of the system's components. No logical, easy-to-use techniques to analyze and communicate a common sense systems approach to management were available. Management recognized that limited improvement resources must be focused in those areas that would provide the most impact in improving the bottom line. Because of the impending closure of the Sacramento Air Logistics Center, it became very important to find effective mechanisms for dealing with change and helping employees to obtain the widest possible range of choices for their futures. TOC provided a methodology to ensure enduring systemic results.

As part of the initial training to senior management, each manager produced a root cause analysis of problems within his or her area of responsibility. A TOC instructor/consultant was trained within the organization. The logic

analyses were communicated to key personnel for buy-in and implementation of improvement efforts. The result was the breakdown of adversarial relationships and the creation of partnerships among organizations and leaders. System performance factors such as profit and loss and number of total paid hours were tracked and trends were observed. Daily use of TOC logic analysis and communication techniques have been taught to managers and key personnel within the organization. This approach builds on the organization's quality culture and focuses on what is really important to the organization, while "de-mystifying" TOC.

Implementing TOC provided valuable lessons learned including the necessity for continuous improvement, the need to demonstrate the logic of a new approach and its benefits before personnel will adopt it, and the need to get personnel to try TOC techniques before they can believe in their own ability to use them successfully. Since adopting TOC, SMSD has been able to focus on what is important, and its quality culture is consequently stronger. Improvement efforts are easier to implement. The organization has moved into a more attractive financial position. Specific cases of the application of TOC tools have produced dramatic results (Table 2-1).

Table 2-1. Theory of Constraints (TOC) in Practices Within the Manufacturing Services Division

Topic	Requirement	Theory of Constraints Tool	Results
Material Requirements Contract	Decrease production lead time to customer.	Current Reality Tree for TIM (Cause-Effect Logic Diagram)	Typical material delivery time driven down from 90 days average to 5 days.
IMPAC Credit Card	Quick and effective way to buy commercially available parts or service	Current Reality Tree for TIM	Parts and services are obtained same day as opposed to waiting 3-12 weeks for the procurement process. Three credit cards have been obtained for TIM with a \$2500 limit per purchase, \$10,000 a month each. This allows TIM to operate more like a private business and respond immediately to urgent requirements.
Manufacturing Engineering Core Expertise	Bridge the gap between design and production.	Current Reality Tree for TIM	Four manufacturing engineers are working in the division developing manufacturing processes and/or flows for new and existing workloads. TIM throughput (and profitability) has increased.
Casting Emission Reduction Program (CERP)	Achieve the ambitious target of getting the CERP Mobile Team ready for the national survey.	Intermediate Objective Map (Simplified Prerequisite Tree)	Took a large group of diverse technical experts and converted them into a team operating with a coherent strategy and synchronized tactics.
Manufacturing Services Division Strategic Management Efforts	Continuous improvement and reinforcement of TOC analysis and communication methods. Specific task being worked: achieving the ambitious target of being ready for privatization.	Intermediate Objective Map and Transition Trees	Gives a clearly defined, logical road map of objectives that must be achieved by the management team in order to make the target. Verifies the logic of the actions being taken. Obtains buy-in from all team members.
Casting Emission Reduction Program (CERP)	Obtain Procurement buy-in for contracting method change. (Note: this was a student's homework assignment from session 1 of the Management Skills Workshop.)	Negotiating Conflict Cloud (Logical Conflict Diagram)	Contracting officer broke the conflict on her side and made the changes recommended by the CERP engineering staff. The changes allowed contract continuity. This prevented an approximate one year delay in the construction contract for the foundry.

Section 3

Information

Design/Test

Amphibious Assault Vehicle Technical Data Package

The Marine Corps solicited help from the SMSD to reverse-engineer the transmission castings for its amphibious assault vehicle (AAV). When the Marine Corps procured the AAV twenty years ago, the technical data package for items such as the transmission castings was not procured from the contractor. Throughout the life cycle of the AAV—a critical piece of equipment for Marine Corps operations—the transmission housing and components required significant levels of maintenance and repair, and timely completion of these repairs was sometimes crucial. The Marine Corps was therefore faced with the problem of the contractor not being able to provide the technical data package for four different variations of the transmission castings in a timely and economical manner. The contractor required \$1M to produce the technical data as well as an 18-month lead time for the component. This option did not meet Marine Corps needs, and the other option of reprocurement of these critical components was also unacceptable because of time constraints.

Therefore, after contact by the Marine Corps, SMSD used CMMs and non-destructive inspection techniques on sample castings to develop a complete data package. For the interior passages that were difficult to measure, unique ultrasonic inspection methods were incorporated. X-rays were taken to assess quality problems (such as cracking) with the sample castings. By utilizing these non-destructive inspection techniques and a CAD system, full-scale manufacturing and casting drawings were developed.

This effort incorporated 33 engineering change proposals for 13 additional components for the Marine Corps AAV transmission. With an investment of \$240K, the Marine Corps can now control future procurement of the AAV transmission components in a full and open competition process. This accounts for a savings to the taxpayer of approximately \$760K.

Eddy Current

At SMSD, a wide variety of commercially available eddy current hardware is in use. This equipment includes state-of-the-art phase analysis eddy current hardware as well as basic impedance-based measurement devices. Eddy cur-

rent testing is used for detecting surface breaking cracks and subsurface discontinuities in metallic materials. This technique has been used extensively for the detection of cracks emanating from bolt/rivet holes in aircraft skins. The devices at SMSD are used in a point measurement mode such as scanning one bolt hole at a time with a hand scanner.

SMSD's phase analysis capability for titanium components is unique in the Air Force community, and procedures have been developed at SMSD to use a Zetec MIZ 40 for the detection of corrosion in the lap joints on the KC 135. The eddy current inspection capability was recently further extended by the introduction of a magneto-optic device to allow viewing the eddy currents in a 4-inch by 4-inch area (flat surfaces). The technique is sensitive to cracks (in particular around bolt/rivet holes) and subsurface corrosion. The applicability of this technique for in-field use has been facilitated by the use of a heads-up display that relieved the operator from having to try and view a monitor while at the same time maintaining control at the point of inspection.

Personnel at SMSD not only support eddy current inspection requirements within the facility, they also provide worldwide support, in particular for the A-7 aircraft's lower skin cracking problem. SMSD personnel are active in intra-service work; for example, they wrote the inspection procedure for the Army's Apache helicopter.

Inspection Modeling

A project has been initiated at SMSD to develop algorithms and models for correlating data acquired from NDI systems such as the N-ray, x-ray, and ultrasonic inspection systems, with data on strength characteristics and failure modes. NDI is used to identify flaws in composites-based aircraft components. Since it is currently difficult to assess the potential impact of a detected flaw, parts are often replaced or repaired without fully ascertaining the significance of the flaw. An added cost is that the aircraft is not available for service while it is being repaired. Models are needed to assess the impact of cases when multiple small flaws are detected or when unique flaw characteristics dramatically change the actual significance of the flaw on a part's remaining life.

A call for proposals has been initiated under the SBIR program to identify solutions to the inspection modeling problem. Phase I will focus on determining whether or not it is possible to achieve objectives using current equipment

installed at McClellan. Phase II will develop algorithms to determine the impact of imperfections and to build algorithms using the Marine Corp's Harrier Jump jet wing as a test area.

Manufacture of Fuselage Station 880-890 Beams for the KC-135 Aircraft

To assist in the logistics supportability of the Air Force's KC-135 aircraft maintenance program, SMSD developed an alternative approach for manufacturing the fuselage station 880 and 890 beams. There is cracking in the beams because of the age of the aircraft. Although repair of the cracked beams normally required replacement from a single source supplier who was costly, and required a long lead time.

A proposal was issued that instead of using a die forging of 7075 aluminum alloy for the part, the beams could be machined from 7050 forged aluminum alloy billets. The properties for the proposed material, although not a die forging, appeared to correlate very closely to the requirements originally specified by the original design engineer. This proposal was accepted by the Oklahoma City Air Logistics Center's engineering staff for a manufacturing prototyping effort which was performed by SMSD.

Prototyping this complex part was not a simple task and required considerable planning by CNC programmers, planners, engineers, and skilled machinists. This team effort resulted in the production of a prototype beam which was submitted to the Oklahoma City Logistics Center's engineering staff for thorough first article testing. The test results indicated that the prototype beam could indeed be substituted successfully for the original manufacturer's design. Consequently, work orders for production of the new beam configuration were issued to SMSD.

Over 400 beams have been produced on an accelerated schedule in support of this program resulting in a improved KC-135 fleet readiness, a critical aspect of national defense. Besides the improved delivery schedule, the cost of production (through continuous process improvement) is about 20% less per part than the cost of production using the die forging method. This translates into substantial savings for the Air Force when applied to the entire fleet retrofit program. Improved quality, reduced program cost, and improved delivery schedules for parts as well as having an alternative source for manufacture earmarks this highly successful program for the Air Force, initiated by the creative efforts of SMSD.

Reverse Engineering

With attention on defense spending and resource draw-down, SMSD realized the importance of capturing a reverse engineering workload. SMSD previously had not placed

emphasis on reverse engineering, instead stressing the plentiful incoming production workload. Valuable resources could not be expended on customer requests which required reverse engineering. There was also a lack of high-tech tooling, jigs, and access to CAD/CAM.

However, to enhance its reverse engineering capability, SMSD upgraded its CAD/CAM and machining processes with state of-the-art technology which increased customer support. As the defense workload declined, various SMSD shop functions encouraged the recruitment of customers. When formal technical data was not available, the key skill disciplines such as the shops, engineering, laboratory, and materials converged and developed a cost effective and efficient approach to meet customer requirements.

SMSD has realized that customers have different needs such as turnaround time and component integrity. For example, one customer can allow latitude on the material used in a part that does not compromise integrity, thereby allowing for a more rapid turnaround time. However, another customer may require more specific needs which in turn increase the cost. SMSD can accommodate both in its reverse engineering efforts, and furnishes customers with safe parts at lower costs and ultimately, a new manufacturer source. Complete and accurate files are maintained on the project during the reverse engineering process. SMSD produces level three drawings that the customer can use for follow-on production wherever the work is performed. However, customers typically have returned to SMSD for follow-on work because of the cost savings compared to other agencies and quality of the work.

The organizational policy shift to support reverse engineering has greatly enhanced customer satisfaction. SMSD has captured new and diverse workloads for the shops resulting in the expansion of the skill base beyond just aircraft parts. An example of this is the reverse engineering of four transmission castings for the Marine Corps. This effort incorporated 33 engineering change proposals for 13 additional components that saved the customer approximately \$750K.

Production/Facilities

Alternatives to Chrome Plating

In response to EPA legislation requiring disposal of waste materials and phase-out of chromate use, SMSD initiated efforts to seek out alternative coating methods. SMSD is equipped with an extensive plating facility offering continuous or batch anodizing and conversion coating of aluminum parts which vary in size and number. It used chromate for anodizing and conversion coating to prepare metal surfaces prior to adhesion or to provide a protective, controlled barrier against corrosion.

A research contract with the Mitre Corporation identified two substitutes – High Velocity Oxygen Fuel (HVOF) and the Takata process – that are being evaluated at SMSD to determine whether they could be qualified replacements to chromate. They have to meet criteria of wear resistance, corrosion protection and adhesion. In addition to meeting EPA requirements, other benefits to replacing chrome are the potential for more uniform deposition and reduced cost per part. (Chrome plating usually requires rework to achieve uniform coating thickness on complex parts.) Lastly, the candidate coating processes being considered potentially can result in parts with more precise tolerances than achieved by chromate coatings.

Chaff Flare Box Injection Molding

SMSD re-engineered a chaff flare box over a panel in response to an aircraft operational problem that private contractors were unable to correct. These chaff flare box cover panels were originally manufactured from fiberglass, required 40 fasteners to install, cracked when installed, and did not protect the firing mechanism from corrosion.

The basis of the solution was to use an injection molded part made from a material that is resistant to corrosion, has a reduced number of parts, requires fewer fasteners (from 40 to 4), and is applicable to a wide range of aircraft using the ALE-40 Chaff/Flare System. The mold for this part was designed and built by the SMSD staff for use on its 225-ounce injection molding machine. This 225-ounce capacity Cincinnati Milacron Model H1500-225 injection molding machine operates at 20,000 psi and 1500-ton clamp pressure. The machine, together with a 14-ounce and a 5-ounce machine constitute the only injection molding machines in the Air Force Materiel Command. They were installed to expand the use of injection molded parts to replace original materials on existing aircraft such as the chaff flare box cover panels.

The finished thermoplastic part is lighter in weight, easier to install and maintain, has fewer parts, and generally performs better when compared to the original unit. SMSD has produced 28,000 parts to date at a cost of \$63 each. This part replaces an original equipment part that cost \$400 each, representing a \$9M cost savings.

Environmental Issues

SMSD has taken a proactive leadership role in the area of environmental improvements and compliance. Several projects are underway to renovate facilities and bring them into compliance with all current environmental requirements:

An extensive environmental \$17.9M restoration effort

for SMSD's 20-year old plating shop. The Caustic Recycling System for Chemical Milling operations. This system will eliminate the disposal of spent chemical milling solutions through recycle and reuse, saving not only the cost of disposal but also the cost of replenishment.

The Electrodialysis Unit is used for cleaning chrome plating solutions. This unit will extend the life and improve the output of the chrome plating solutions.

High Velocity Oxygen Fuel

SMSD is upgrading its coating application capabilities and eliminating traditional chrome plating activities to comply with environmental regulations. Jet HVOF equipment is being procured that efficiently uses high kinetic energy and controlled BTU output to produce dense, very low porosity coatings that exhibit high bond strength with extremely fine-sprayed finishes.

SMSD currently uses metal and thermal spray processing for coating many metal components such as tooling, shafts, and pistons. To upgrade the facilities capabilities and conform with environmental restrictions, SMSD and Environmental Management performed a two-year study to locate an alternative to chrome plating, and the HVOF process was recommended. Coating with low residual thermal stresses can be sprayed to thicknesses not normally associated with dense thermal spray coatings. This process uses an oxygen fuel mixture consisting of oxygen and propylene, propane, or hydrogen to produce quality coatings. The system utilizes higher velocity deposition (approximately 2000 feet per second) resulting in a higher density coating with increased hardness and lower porosity. These benefits result in higher bond strength and longer lasting parts.

After installation, the system will require a year of manufacturing development to characterize the new process capabilities and applicability of different material systems. The planned system will initially utilize tungsten carbide powder as the preferred material deposition system. Environmental requirements include the implementation of a material collection and disposal system. As decibel levels for this process are expected to be higher than current metal or thermal spray application (111-115 decibels), the operator will work outside of the booth using a fully automated, computer controlled system, eliminating any exposure to the high noise levels.

SMSD is currently purchasing this equipment for HVOF capability with planned implementation in late 1996. The estimated cost of the HVOF system is \$500K to \$700K. Anticipated benefits include higher quality coatings, decreased processing time and rework, lower residual stresses for longer lasting components, and lower cost oxygen/propylene delivery system materials.

Laser Reverse Machining

SMSD is installing a Laser Reverse Machining cell to enhance its ability to perform depot-level repair of worn or damaged aircraft metallic parts. The present method involves building up worn or damaged areas by flame spraying, welding, or cladding the damaged areas with a compatible material, then remachining the part to the original manufacturing specifications. This process is costly and provides limited service life to the repaired items. The Laser Reverse Machining cell will allow SMSD to perform the same tasks with much higher precision and at a significant cost reduction.

The basis of this planned cell is a six-axis, robot controlled, 2400-3000 KW YAG laser which will be linked to several processes such as welding, cladding, etching, and machining through fiber optic lines. The new laser cell will provide the central process for more accurate cutting and higher precision application of the cladding material. The ability to control application of cladding or welding will reduce the time required for finish machining and is expected to extend the repair capability to include parts that were previously considered non-repairable. The service life of materials repaired by this process has also increased four to five times over conventional repaired items because of the reduction of heat-affected zones created during rework processing. Engineering studies have shown that time savings of 100-300% can be expected when rework of parts is accomplished with LRM. That anticipated savings – with the associated turnaround time reduction – will result in better value to the customers of SMSD.

Magnetic Particle and Penetrant

Portable and stationary magnetic particle and dye penetrant tests are performed at SMSD to detect surface-breaking cracks and subsurface cracks with depths no greater than approximately five mils – for magnetic particle – in metallic structures.

The testing shop at SMSD, designated MA3 (production capacity), has demonstrated excellent productivity. In FY95 the shop achieved 125% effectiveness based on established labor standards. This shop maintains its own equipment as well as providing maintenance services to other military installations. The two stationary magnetic particle inspection systems at SMSD average a throughput of 18,000 ferrous parts per month, of which 75% are hydraulic components. The stationary penetrant system averages a throughput of 14,000 non-ferrous parts per month. Parts come into the shop in the cleaned condition, allowing for a typical turnaround time of one day. When required, in-situ magnetic particle and dye penetrant testing can be performed with portable equipment at the aircraft. This shop is set up

to detect defects, determine the defect type, and report this information to the part owner who then determines serviceability.

No-Bake Sand System

A no-bake sand system is being installed in the foundry at SMSD to replace the typical aluminum sand casting operation in which the core is baked to remove excess gases. Instead of manually mixing the sand, binder, and catalyst, packing it into a mold, placing the core into the mold, and pouring molten metal inside, the No-Bake Sand System offers automated mold making that requires no baking.

SMSD has extended the benefits of the No-Bake Sand System by installing a set of rolling hoods as part of the emission control system over the conveyor. Exhaust air is drawn from under the covered conveyor system and vented to the baghouse dust collection unit located outside the building. The No-Bake Sand System will reduce process time, reduce material cost, improve recovery, and produce cleaner air. For example, the process time is decreased from 45-60 minutes to approximately 10 minutes per casting. Additionally, 80-90% of the sand is recycled. The sand reclamation system automatically breaks down sand and mixes proper amounts of new sand to the reclaimed material. Ultimately, implementation of the No-Bake Sand System will result in higher quality end products.

Plating Shop Rehabilitation

SMSD is renovating its outdated plating shop in three phases to maintain daily operations and meet the needs of SMSD customers. An FY94 Military Construction Project funded for \$17.9M is being used to renovate the facility and bring it into compliance with all current environmental requirements. This shop was the subject of a 1992 Enforcement Order issued by the state of California mandating compliance with current environmental standards to remain operational. Several actions as well as other improvements are being corrected by the Military Construction project with expected completion in FY98.

The plating shop will be in compliance with all current environmental standards and requirements with increased efficiency and quality. The project has been designed by engineers and consultants with additional input from all personnel involved in the operation. Weekly planning meetings are held to resolve any problems or bottlenecks and to ensure the project stays on track. When completed, this plating shop will be one of the most modern and environmentally-compliant facilities in the country, capable of producing consistently high quality work in a safer and healthier work environment.

Robotic Painter System

SMSD maintains a large parts painting capability housed in a 20 foot wide by 16 feet high by 20 feet deep paint dryer and booth equipped with a six-axis Robotic Painter System. This system was purchased and installed in 1987 to replace the manual painting operations used on the F-111 aircraft radomes which measure approximately seven feet long and three feet in diameter. The radomes required 12 coats of a rain erosion coating applied evenly to maintain an effective radar cross section. Manual painting for this large surface required two painters 16 hours to complete. Because maintaining consistency in a manual paint application for large surfaces of this type is difficult, radomes were failing electrical test resulting at a 50% rejection rate. Rework required three to four days to complete and schedules were consistently missed.

The introduction of the six-axis Robotic Painter System provided control of the process. The painter system is equipped with a self-programming capability that records the path of the robot arm as manipulated by the operator. The teaching operation is performed only once manually by the operator and the system computer repeats the maneuver automatically whenever commanded.

With the installation of the Robotic Painter System, radomes can be painted in 10 hours by only one operator. Rejection rates have been reduced to zero, rework is no longer required, and all schedules are being met. The painter system provides a consistent and repeatable operation and is especially valuable for large parts painting.

Set-up Reduction Project

In a continuing effort to increase operational efficiency and effectiveness, SMSD has developed a program to reduce the cost of machining in the job shop/just in time environment. This program applies Single Minute Exchange of Dies (SMED) to perform all machine set-ups in 10 minutes or less. The central tool control processes and procurement did not respond to machining operations requirements. Shop orders for tools were processed monthly, and inventory and tool integration into the local stock system was difficult. Studies indicated that machinists spent nearly 20% of their time setting up machines, but half of that time was devoted to searching for, fixing, and working with the tools they find. Throughput capability and effectiveness was reduced resulting in machinist, supervisor, procurement staff, and customer dissatisfaction.

In early 1994, the SMSD and acquired a new tool and die supervisor, and a study team was formed to focus on standardizing cutting tools, creating a cutting tool inventory database, visual tool control, and enhancing cutting tool availability. Facing an impending base closure and pros-

pects of privatization, operations had to be refined, and tooling procurement costs had to be reduced.

To begin implementing SMED, all cutting tools, drills, and precision measurement device have been manually inventoried, and SMSD anticipates loading that information into a database. Under the current plan, a full-service supplier will be contracted to perform functions such as procurement actions, tool issue and inventory, and possibly JIT delivery to meet specific needs. Another significant change is to develop a visual storage system so the tooling stored in drawers and cabinets are visible and secure. Because tool location is critical to effective operations, SMED will locate approximately 70-80% of the required tools near the job site to minimize set-up time. These operational aspects have been successful in naval shipyards and once implemented, will be as effective for operations within SMSD.

SMSD maintains that SMED will help decrease set-up times resulting in increased throughput. Unnecessary procurement actions would be eliminated resulting in reduced tooling expenses. An accurate inventory and tracking system of all tools would help decrease the need for excess tools. Most importantly, machine shop organization would be optimized resulting in increased profits.

Shop Floor Parts Tracking System Overview

SMSD is organizing a Shop Floor Parts Tracking System (SF-PTS) to report status and statistics on parts, kits, subassemblies, and assemblies in inventory as they are processed on the shop floor. This system will be the cornerstone of a future paperless automated agile manufacturing environment.

SMSD considers ISO 9000 a prerequisite for future business, with an internal goal of April 1996 for ISO implementation. The current environment at SMSD illustrates the need for SF-PTS. Labor rates are high in comparison to other areas of the country or other DOD installations; consequently, work must be performed right the first time to remain competitive. Traditionally scrap rates, rework, and process statistics have not been tracked within the Division. Inventory count was performed by physical inspection resulting in inaccuracies; no accessible ISO 9000 pedigree information for rawstock and assemblies was available.

SMSD initiated factory floor management changes in 1992 by exploring Flexible Computer Integrated Manufacturing. SMSD employees reviewed major DOD programs, and awarded a contract to the South Carolina Research Authority in 1993 who provided a conceptual architecture detailing what the future system would look like, and provided a cost justification and roadmap for future

implementation. SMSD then initiated quick start projects. Based on the South Carolina Research Authority recommendations in parts tracking and inventory management, SMSD selected the T-38 Canopy Frame Program as the pilot project because the program impacts several areas of shop floor operations. The full system will be implemented in a modular fashion.

The SF-PTS system uses bar codes and scanning devices for required data inputs with scanning devices located across geographically dispersed repair facilities. The system runs across an Ethernet network, is UNIX based, and uses ORACLE as the database engine. The system currently offers 72 user interface screens. Personnel with a password can access the system; however, most schedulers, foremen, and planners currently view the system data via e-mail reports automatically generated and mailed nightly. The system tracks all raw stock by manufacturer, batch, and lot. This manufacturer's information is combined with the manufacturing and repair process information and tracked through part assembly. The information is then captured in an ISO 9000 report stored permanently on an optical disk.

While the SF-PTS has not fully been implemented, benefits are characterized by implementation of a similar system at the San Antonio Air Logistics Center. These benefits include increased throughput by 35-40%, reduction in inventory levels of 50-70%, reduced production delays, and

the ability to achieve future ISO 9000 compliance. Future steps for SMSD include the development a common data dictionary, a common data model, and integration of the different software being used.

Ultrasonic Inspections

Ultrasonic testing, extensively used to detect internal defects in structures, has a longstanding history of successful inspection at SMSD of both metallic and composite aircraft components. Inspections range from metal-to-metal and composite-to-composite bonded structures to skin-to-core bonds and solid components. Depending on the application, equipment used for ultrasonic inspections include tap hammers (sonic), bond testers, and a squirter system. The ultrasonic inspection shop has two ASNT Level III as well as 12 Level II certified inspectors.

The main component of the squirter system is a gantry system which positions and scans a pair of ultrasonic transducers following a preprogrammed contour of the part shape. The ultrasonic signals produced by the piezoelectric transducers are carried to and from the part via a water column (provided by the squirter). The inspection may be conducted in transmission (two-sided) or pulse echo (one-sided) modes. This system is capable of scanning large flat parts such as aircraft wings and has been used effectively over a number of years for inspection of various aircraft components. This inspection is a requirement for detection of skin-to-core disbands on the F-111 aircraft.

Introduction of this squirter system has resulted in reduced turn-around time. It also provides archival information for comparison with other inspection results such as from the N-ray and x-ray systems, and decision making efforts regarding service life of the part. For example, in a disbond repair scenario, ultrasonic data would be provided to the engineer who would then use this information to decide the extent of the required repair.

SMSD will soon be installing a Laser Ultrasonic Inspection System (Figure 3-1). This system will provide a non-contact, remote inspection capability for simple to complex shaped parts up to 12 feet by 40 feet with no specific description of part shapes

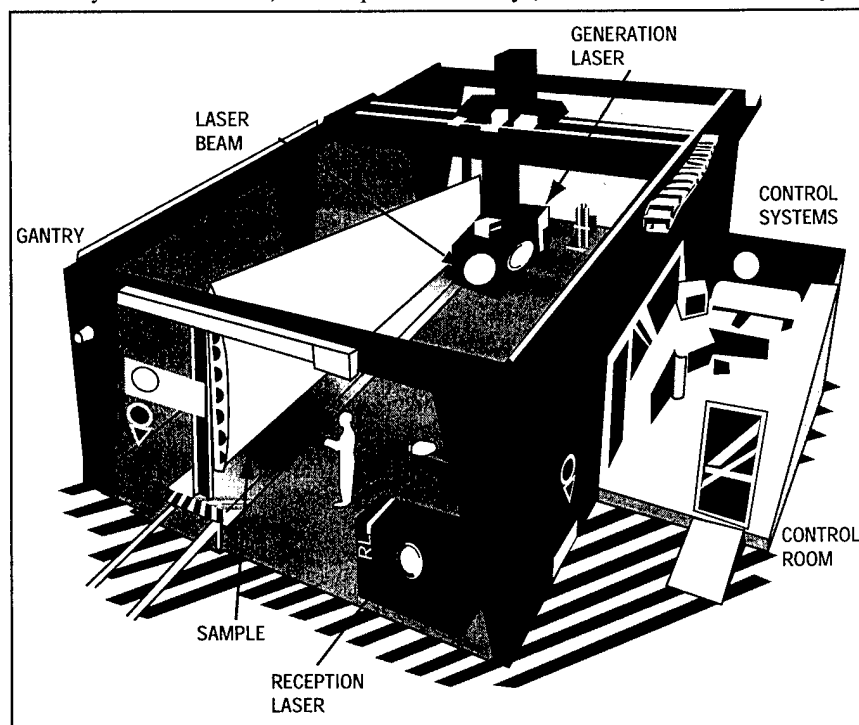


Figure 3-1. Ultrasonic Inspection System

programmed into the system. This system will be used for surface mapping of parts as well as ultrasonic inspections.

Vacuum Welding Chamber

SMSD is completing installation of a vacuum welding chamber for welding titanium components. Manufactured by Vacuum Atmospherics Company, the Model QP-30 vacuum chamber is expected to be operational in early 1996. This unit replaces an inadequate two-foot by one-foot chamber with a very small viewing port.

The new unit is a fully automated chamber that has a working area of four feet by seven feet by four feet with two working stations per side. Each side allows full visibility into the work area, and one of the working stations has been modified to allow for work on larger parts. The new vacuum welding chamber is expected to meet larger workloads that will accommodate state-of-the-art titanium and corrosion-resistant steel welding equipment. This chamber will support the use of very demanding clean room welding atmospheres where trace amounts of oxygen are detrimental to acceptable welds.

Water Jet Cutting

SMSD recently installed an abrasive water jet cutter for added versatility in its machining operations. This system will help SMSD more economically manufacture products and process materials that normally cannot be processed by conventional machining methods. The water jet cutter eliminates many conventional saws, shears, and cutting operations normally associated with the manufacture of metallic and non-metallic materials, thereby reducing product cost and delivery times.

The heart of the cell is a 55,000-pound psi intensifier pump and a six-axis CNC robot-controlled cutting head. The cell table and robot controller are configured to allow processing of materials up to 6 inches thick, 3.5 feet wide, and 8 feet long. Complex shapes can be machined with high precision and with superior surface finishes. Water jet machining allows elimination of many of the problems inherent with traditional methods of machining and other cutting operations such as heat affected zones and delamination of composite lay-up materials. Additionally, water jet machining reduces the need for expensive tooling and fixturing that would be required for conventional processing.

While water jet machining will not completely replace conventional machining processes at SMSD, it will allow the user to produce many finished parts with a high degree of accuracy and at a reduced cost. The addition of this equipment has greatly enhanced the ability of SMSD to be responsive to customer needs and economically manufacture finished products.

Logistics/Management

Community Involvement

The employees of the SALC, of which SMSD is part, are active in community involvement programs. These programs range from charitable donations to blood drives, school involvement, and recycling efforts.

Over \$1M per year is donated by SALC employees to the Combined Federal Campaign, with 75-80% of that amount staying in the local community. As an incentive to the employees to continue their beneficent donations, SALC provides rewards with several levels of recognition pins. Employees are also accorded four hours of free time off work when they donate blood for the Sacramento metropolitan area. Other employee-involvement programs include Operation Santa Clause and the Adopt-A-School Program. The Adopt-A-School Program currently has over 100 employees actively participating as mentors, teaching assistants, tutors, and career days counselors. The base contributes excess personal computers excess to the local school for use in the classrooms.

As good stewards of the community, SALC updated the industrial waste water treatment plant to a closed loop system which reuses over 90% of the water pumped into the industrial facility. This treatment plant saves the community millions of gallons of water yearly and significantly reduces the amount of industrial waste returned to the waste stream.

SMSD is involved in CERP, a \$50M project with USCAR to develop a cost effective/environmentally-compliant foundry. As the research lead and beta test site, the community of Sacramento will be the first to benefit from the process with cleaner air emissions from this foundry.

SMSD has several technology transfer agreements that contribute to the advancement of the sciences. Most notable is an agreement with the University of California, Davis Medical Center to study neutron boron capture therapy on cancer patients who have inoperable localized malignant brain tumors. Working with the university and allowing the use of SMSD's neutron reactor for research in a regional treatment center for previously inoperable brain tumors will be established.

ISO 9000 Implementation Approach

SMSD is developing a quality assurance plan on a current production program that will serve as a prototype blueprint for incorporating Air Force programs into the ISO 9000 structure. The program to manufacture special refrigerated field shelters will be a pilot program for the SALC to become ISO 9000 compliant. It will also serve to set customer-oriented quality goals and objectives. Although

there is no intent to pursue full certification, this approach will meet Air Force objectives and provide the SALC with training and experience in working the ISO 9000 structure.

During recent years, downsizing and restructuring forces had worked to eliminate the quality organization and many of the elements of a formal and structured quality assurance system. As a result, quality requirements were not adequately defined or documented – *no* quality plan existed. Statistical techniques for establishing, controlling, and verifying process capabilities and product characteristics were not in effect. This created a need to develop a documented quality system to ensure products conform to requirements, including quality plans for controlling and improving processes.

To accomplish the necessary changes on the refrigerated shelter program, the roles, responsibility, and authority of all personnel who impact quality were defined. A quality assurance plan was developed during the prototype phase of production based on ISO 9000 requirements. The plan was tailored to reflect specific customer requirements. The plan

is scheduled for implementation on the first production run of 14 shelters which will occur in early 1996.

In implementing this approach, SMSD learned that quality policy must be defined and documented and must be relevant to both the supplier's goals and the customer's needs. The quality system must establish and maintain a documented quality system to ensure products conform to specific requirements. Implementation requires a basic organizational change in attitude about quality.

As a result of this approach, SMSD is experiencing a greater awareness about quality, and its culture is changing, and is becoming a prototype for quality assurance plans at the SALC. Anticipated benefits include:

- establishment of a data collection and analysis system to assess implementation benefits and identify trends, cost efficiencies, and customer enhancements;
- increased efficiency and productivity;
- reduced scrap and rework expense; and,
- an overall increase in marketability of the Division as an aid to privatization.

Appendix A

Table of Acronyms

ACRONYM	DEFINITION
AAV	Amphibious Assault Vehicle
CERP	Casting Emission Reduction Program
DOD	Department of Defense
HVOF	High Velocity Oxygen Fuel
IGRIP	Interactive Graphic Robotic Instruction Programming
NDI	Non-Destructive Inspection
N-ray	Neutron Ray
QUEST	Queuing Event Simulation Tool
SALC	Sacramento Air Logistics Center
SF-PTS	Shop Floor Parts Tracking System
SMED	Single Minute Exchange of Dies
SMSD	Sacramento Manufacturing and Services Division
TOC	Theory of Constraints
VR	Virtual Reality

Appendix B

BMP Survey Team

TEAM MEMBER	ACTIVITY	FUNCTION
Bob Jenkins (703) 602-3003	NAVSEA Washington, DC	Team Chairman
Amy Scanlan (301) 403-8100	BMPCOE College Park, MD	Technical Writer
TEAM 1		
Chuck McLean (301) 975-3511	National Institute of Standards and Technology Gaithersburg, MD	Team Leader
Jack Tamargo (707) 642-4267	BMPCOE Vallejo, CA	
Bahram Farahbakhsh (614) 487-5826	Edison Welding Institute Columbus, OH	
Carol Lebowitz (410) 293-3574	Naval Surface Warfare Center Carderock Division Annapolis, MD	
TEAM 2		
Don Hill (317) 306-3781	Naval Air Warfare Center Aircraft Division - Indianapolis Indianapolis, IN	Team Leader
Jennifer Jarrett (703) 696-0344	Naval Air Command Washington, DC	
Mike Thress (615) 574-7413	Department of Energy Oak Ridge National Laboratories Oak Ridge, TN	
Jim Fuss (919) 466-7348	Naval Depot - Cherry Point Cherry Point, NC	
TEAM 3		
Rick Purcell (301) 403-8100	BMPCOE College Park, MD	Team Leader
Larry Halbig (317) 306-3838	Naval Air Warfare Center Aircraft Division - Indianapolis Indianapolis, IN	
Charles Valz (410) 278-6945	U.S. Army Combat Systems Test Activity Aberdeen, MD	

Appendix C

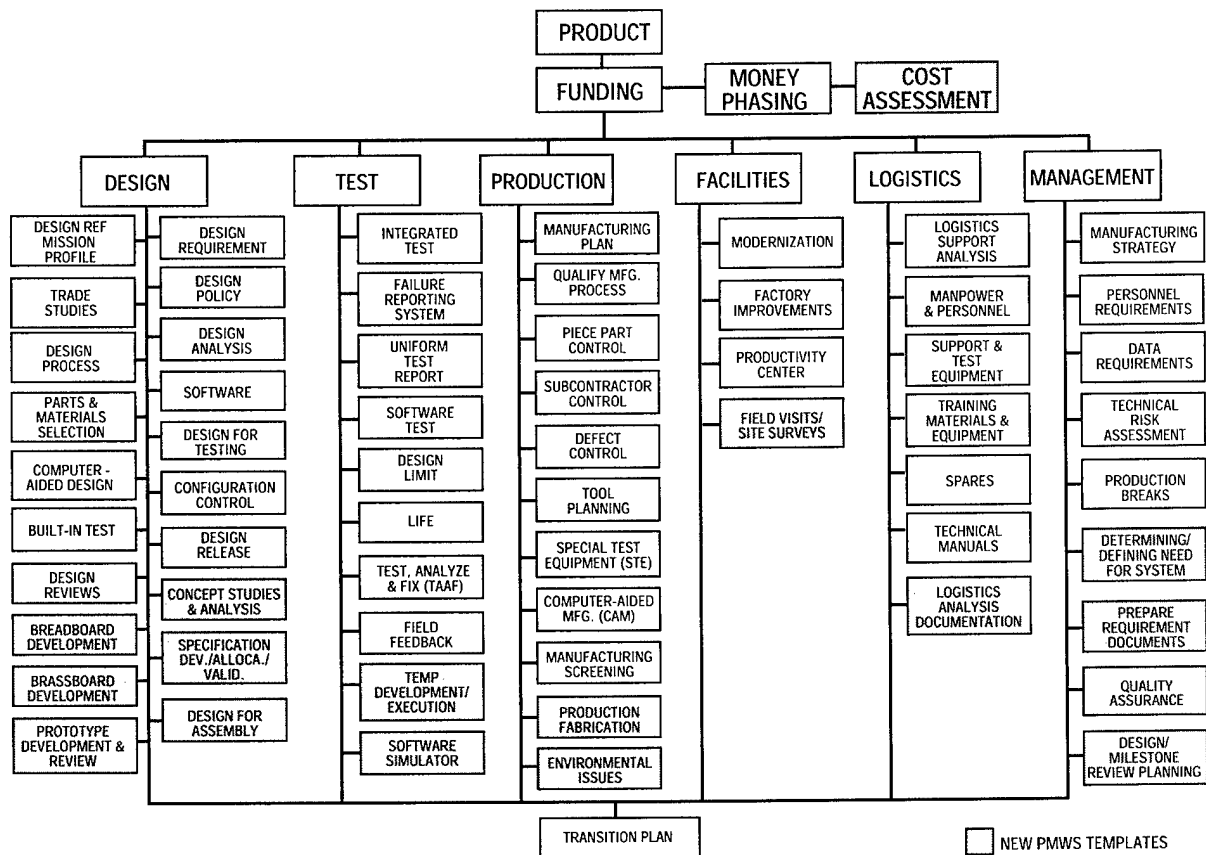
Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing

it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

“CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION”



Appendix D

BMPnet and the Program Manager's Workstation

The Program Manager's Workstation (PMWS) is a series of interrelated software environments and knowledge-based packages that provides timely acquisition and engineering information to the user. This Workstation is hosted on the BMPnet that supports communication nationwide to promote technology transfer and continuous improvement. Access to BMPnet is through modem dial-in, free PMWS software, Internet, World Wide Web, or CD-ROM. Besides PMWS, BMPnet features include communication by electronic mail and file transfer; access to Special Interest Groups on more than 75 topics including producibility and Government specifications; information upload and download capability; and the ability to download BMPnet-resident programs.

PMWS includes **KnowHow**, an electronic library of expert technical assistance, including an intelligent search capability that gets the information users need on the screen in less than three minutes; the Technical Risk Identification and Mitigation System (**TRIMS**), a technical risk management system that may be tailored to the user's needs; the BMP database that contains over 2,000 abstracts on documented best practices; and SpecRite, a performance specification development tool.

KnowHow is . . . Knowledge through an automated and intelligent information access system that speeds the search for required information by up to 95%. Typically, the information needed is on the screen in less than three minutes.

KnowHow features include:

- Personalized acquisition planning guidance, both high and low level, as appropriate.
- Information required for user's specific job.
- Special, logic-driven menu that allows fast access to cut research time by up to 95%.
- On-line user's manual and help.
- Application as a learning tool for new acquisition personnel.

TRIMS brings . . . Insight which identifies and ranks those program areas with the highest risk levels.

TRIMS features include:

- Ability to conduct continuous risk assessments to take preemptive corrective action.
- Tracking capability for key project documentation from concept through production.
- Identification function of goals, personnel, and future activities in development processes.
- Default values for many categories by program type.
- Ability to tailor all fields to suit individual program requirements.
- Reports generation.

The **BMP Database** provides . . . Information that comes directly from verified practices in industry that government experts search out looking at the best to collect answers and solutions.

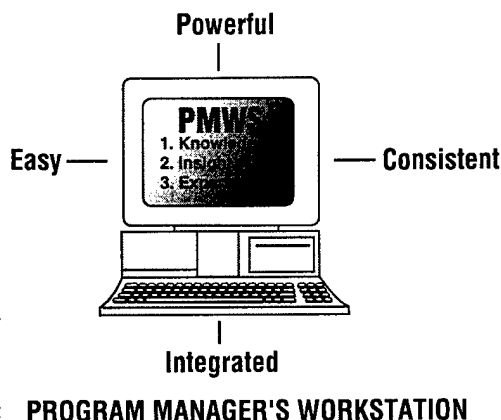
BMP Database features include:

- Information on best practices in manufacturing, design, test, facilities, production, management, and logistics from 80 companies or activities.
- Ability to search for information using a natural language interface.
- Capability to print information to a file, disk or directly to a local printer.
- Phone numbers of points of contact in companies who have been surveyed.

SpecRite can help . . . Develop a performance specification generator based on expert knowledge across the services to guide acquisition personnel in creating specifications for their requirements.

SpecRite features include:

- DOS-base (runs on any PC).
- Organization and structure for the build/ approval process.
- Knowledge-based guidance and assistance.
- Flexible, modular structure.
- Output in MIL-STD 961 format and in WordPerfect 5.1 files.



To access BMPnet, users need a special modem program. This program can be obtained by calling the BMPnet using a VT-100/200 terminal emulation set to 8,N,1. Dial (703) 538-7697 for 2400 baud modems or (703) 538-7267 for 9600 baud and 14.4kb. When asked for a user profile, type: DOWNPC or DOWNMAC <return> as appropriate. This will automatically start the download of the special modem program. Then call back using this program and access all BMPnet functions. The general user account is:

USER PROFILE: BMPNET

USER ID: BMP

Password: BMPNET

If you want a personal account to receive e-mail, forward your request to Ernie Renner (BMP Program Manager) or Brian Willoughby (BMPnet Program Manager at CSC). If you encounter problems, please call (301) 403-8179.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently six Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The six BMP satellite centers include:

Corona, CA

Chris Matzke

Quality Assurance Engineer
Naval Warfare Assessment Division
Code QA-21, P. O. Box 5000
1456 Mariposa Drive
Corona, CA 91718
(909) 273-4992
fax: (909) 273-5315
internet: cmatzke@bmpcoe.org

Louisville, KY

Marshall Bramble

BMP Representative
Louisville Site, Crane Division
Naval Surface Warfare Center
5401 Southside Drive
Louisville, KY 40214
(502) 364-5272
fax: (502) 364-5272
internet: mbramble@bmpcoe.org

Oak Ridge, TN

Tammy Graham

BMP Representative
Martin Marietta Energy Systems
P. O. Box 2009, Bldg. 9737
MS 8091
Oak Ridge, TN
(615) 576-5532
fax: (615) 574-2000
internet: tgraham@bmpcoe.org

Rockford, IL

Dean Zaumseil

Mid-Western Representative
3301 North Mulford Road
Rockford, IL 61114
(815) 654-5530
fax: (815) 654-4459
internet: <adme3dz@rvcux1.rvc.cc.il.us>

Vallejo, CA

Jack Tamargo

West Coast Representative
257 Cottonwood Drive
Vallejo, CA 94591
(707) 642-4267
internet address: jtamargo@bmpcoe.org

York, PA

Sherrie Snyder

Manager, Information Services
MANTEC, Inc.
P. O. Box 5046
York, PA 17405
(717) 843-5054
fax: (717) 854-0087
internnet: <snyderss@mantec.org>

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the GreatLakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Dr. Roger Fountain
Center of Excellence for Composites Manufacturing Technology
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3705
FAX: (803) 822-3730
frglcc@aol.com

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
Plymouth Executive Campus
Bldg 630, Suite 100
630 West Germantown Pike
Plymouth Meeting, PA 19462
(610) 832-8800
FAX: (610) 832-8810
<http://www.engriupui.edu/empf/>

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve manufacturing productivity and part

reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:

Mr. Richard Henry
National Center for Excellence in Metalworking
Technology
1450 Scalp Avenue
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2799
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:

Mr. David P. Edmonds
Navy Joining Center
1100 Kinnear Road
Columbus, OH 43212-1161
(614) 487-5825
FAX: (614) 486-9528
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The COE also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:

Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035
(301) 743-4417
DSN: 354-4417
FAX: (301) 743-4187
mt@command.nosih.sea06.navy.mil

Manufacturing Science and Advanced Materials Processing Institute

The Manufacturing Science and Advanced Materials Processing Institute (MS&MPI) is comprised of three centers including the National Center for Advanced Drivetrain Technologies (NCADT), The Surface Engineering Manufacturing Technology Center (SEMTC), and the Laser Applications Research Center (LaserARC). These centers are located at The Pennsylvania State University's Applied Research Laboratory. Each center is highlighted below.

Point of Contact for MS&MPI:

Mr. Dennis Herbert
Manufacturing Science and Advanced Materials
Processing Institute
ARL Penn State
P.O. Box 30
State College, PA 11804-0030
(814) 865-8205
FAX: (814) 863-0673
dbh5@psu.edu

- **National Center for Advanced Drivetrain Technologies**

The NCADT supports DOD by strengthening, revitalizing, and enhancing the technological capabilities of the U.S. gear and transmission industry. It provides a site for neutral testing to verify accuracy and performance of gear and transmission components.

Point of Contact for NCADT:

Dr. Suren Rao
National Center for Advanced Drivetrain
Technologies
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-3537
FAX: (814) 863-1183
http://www.arl.psu.edu/drivetrain_center.html/

- **Surface Engineering Manufacturing Technology Center**

The SEMTC enables technology development in surface engineering—the systematic and rational modification of material surfaces to provide desirable material characteristics and performance. This can be implemented for complex optical, electrical, chemical, and mechanical functions or products that affect the cost, operation, maintainability, and reliability of weapon systems.

Point of Contact for SEMTC:
Surface Engineering Manufacturing Technology
Center
Dr. Maurice F. Amateau
SEMTC/Surface Engineering Center
P.O. Box 30
State College, PA 16804-0030
(814) 863-4214
FAX: (814) 863-0006
http://www.arl.psu.edu/divisions/arl_org.html

Point of Contact:
Dr. John Crisp
Gulf Coast Region Maritime Technology Center
University of New Orleans
Room N-212
New Orleans, LA 70148
(504) 286-3871
FAX: (504) 286-3898

- **Laser Applications Research Center**

The LaserARC is established to expand the technical capabilities of DOD by providing access to high-power industrial lasers for advanced material processing applications. LaserARC offers basic and applied research in laser-material interaction, process development, sensor technologies, and corresponding demonstrations of developed applications.

Point of Contact for LaserARC:
Mr. Paul Denney
Laser Center
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-2934
FAX: (814) 863-1183
http://www.arl.psu.edu/divisions/arl_org.html

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and will focus primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas will focus on process improvements.

Appendix G

Completed Surveys

BMP surveys have been conducted at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

COMPANIES SURVEYED

Litton
Guidance & Control Systems Division
Woodland Hills, CA
October 1985 and February 1991

Texas Instruments
Defense Systems & Electronics Group
Lewisville, TX
May 1986 and November 1991

Harris Corporation
Government Support Systems Division
Syosset, NY
September 1986

Control Data Corporation
Government Systems Division
(Computing Devices International)
Minneapolis, MN
December 1986 and October 1992

ITT
Avionics Division
Clifton, NJ
September 1987

UNISYS
Computer Systems Division
(Paramax)
St. Paul, MN
November 1987

Honeywell, Incorporated
Undersea Systems Division
(Alliant Tech Systems, Inc.)
Hopkins, MN
January 1986

General Dynamics
Pomona Division
Pomona, CA
August 1986

IBM Corporation
Federal Systems Division
Owego, NY
October 1986

Hughes Aircraft Company
Radar Systems Group
Los Angeles, CA
January 1987

Rockwell International Corporation
Collins Defense Communications
(Rockwell Defense Electronics
Collins Avionics and
Communications Division)
Cedar Rapids, IA
October 1987 and March 1995

Motorola
Government Electronics Group
Scottsdale, AZ
March 1988

General Dynamics
Fort Worth Division
(Lockheed Martin Tactical Aircraft Systems)
Fort Worth, TX
May 1988 and August 1995

Hughes Aircraft Company
Missile Systems Group
Tucson, AZ
August 1988

Litton
Data Systems Division
Van Nuys, CA
October 1988

McDonnell-Douglas Corporation
McDonnell Aircraft Company
(McDonnell Douglas Aerospace (St. Louis))
St. Louis, MO
January 1989 and May 1995

Litton
Applied Technology Division
San Jose, CA
April 1989

Standard Industries
LaMirada, CA
June 1989

Teledyne Industries Incorporated
Electronics Division
Newbury Park, CA
July 1989

Lockheed Corporation
Missile Systems Division
Sunnyvale, CA
August 1989

General Electric
Naval & Drive Turbine Systems
Fitchburg, MA
October 1989

TRICOR Systems, Incorporated
Elgin, IL
November 1989

TRW
Military Electronics and Avionics Division
San Diego, CA
March 1990

Texas Instruments
Defense Systems & Electronics Group
Dallas, TX
June 1988

Bell Helicopter
Textron, Inc.
Fort Worth, TX
October 1988

GTE
C³ Systems Sector
Needham Heights, MA
November 1988

Northrop Corporation
Aircraft Division
Hawthorne, CA
March 1989

Litton
Amecom Division
College Park, MD
June 1989

Engineered Circuit Research, Incorporated
Milpitas, CA
July 1989

Lockheed Aeronautical Systems Company
Marietta, GA
August 1989

Westinghouse
Electronic Systems Group
Baltimore, MD
September 1989

Rockwell International Corporation
Autonetics Electronics Systems
Anaheim, CA
November 1989

Hughes Aircraft Company
Ground Systems Group
Fullerton, CA
January 1990

MechTronics of Arizona, Inc.
Phoenix, AZ
April 1990

Boeing Aerospace & Electronics
Corinth, TX
May 1990

Textron Lycoming
Stratford, CT
November 1990

Naval Avionics Center
Indianapolis, IN
June 1991

Kurt Manufacturing Co.
Minneapolis, MN
July 1991

Raytheon Missile Systems Division
Andover, MA
August 1991

Tandem Computers
Cupertino, CA
January 1992

Conax Florida Corporation
St. Petersburg, FL
May 1992

Hewlett-Packard
Palo Alto Fabrication Center
Palo Alto, CA
June 1992

Digital Equipment Company
Enclosures Business
Westfield, MA and
Maynard, MA
August 1992

NASA Marshall Space Flight Center
Huntsville, AL
January 1993

Department of Energy-
Oak Ridge Facilities
Operated by Martin Marietta Energy Systems, Inc.
Oak Ridge, TN
March 1993

Technology Matrix Consortium
Traverse City, MI
August 1990

Norden Systems, Inc.
Norwalk, CT
May 1991

United Electric Controls
Watertown, MA
June 1991

MagneTek Defense Systems
Anaheim, CA
August 1991

AT&T Federal Systems Advanced
Technologies and AT&T Bell Laboratories
Greensboro, NC and Whippany, NJ
September 1991

Charleston Naval Shipyard
Charleston, SC
April 1992

Texas Instruments
Semiconductor Group
Military Products
Midland, TX
June 1992

Watervliet U.S. Army Arsenal
Watervliet, NY
July 1992

Naval Aviation Depot
Naval Air Station
Pensacola, FL
November 1992

Naval Aviation Depot
Naval Air Station
Jacksonville, FL
March 1993

McDonnell Douglas Aerospace
Huntington Beach, CA
April 1993

Crane Division
Naval Surface Warfare Center
Crane, IN and Louisville, KY
May 1993

R. J. Reynolds Tobacco Company
Winston-Salem, NC
July 1993

Hamilton Standard
Electronic Manufacturing Facility
Farmington, CT
October 1993

Harris Semiconductor
Melbourne, FL
January 1994

Naval Undersea Warfare Center
Division Keyport
Keyport, WA
May 1994

Kaiser Electronics
San Jose, CA
July 1994

Stafford County Public Schools
Stafford County, VA
July 1994

Lockheed Martin
Electronics & Missiles
Orlando, FL
April 1995

Wainwright Industries
St. Peters, MO
June 1995

Sacramento Manufacturing and Services Division
Sacramento, CA
October 1995

Philadelphia Naval Shipyard
Philadelphia, PA
June 1993

Crystal Gateway Marriott Hotel
Arlington, VA
August 1993

Alpha Industries, Inc
Methuen, MA
November 1993

United Defense, L.P.
Ground Systems Division
San Jose, CA
March 1994

Mason & Hanger
Silas Mason Co., Inc.
Middletown, IA
July 1994

U.S. Army
Combat Systems Test Activity
Aberdeen, MD
August 1994

Sandia National Laboratories
Albuquerque, NM
January 1995

Dayton Parts, Inc.
Harrisburg, PA
June 1995

Lockheed Martin
Government Electronics Systems
Moorestown, NJ
October 1995

INTERNET DOCUMENT INFORMATION FORM

A . Report Title: Best Manufacturing Practices: Report of Survey
Conducted at Sacramento Manufacturing and Services Division,
Sacramento, CA

B. DATE Report Downloaded From the Internet: 12/20/01

**C. Report's Point of Contact: (Name, Organization, Address, Office
Symbol, & Ph #):** Best Manufacturing Practices
Center of Excellence
College Park, MD

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: __VM__ Preparation Date 12/20/01

The foregoing information should exactly correspond to the Title, Report Number, and the Date on the accompanying report document. If there are mismatches, or other questions, contact the above OCA Representative for resolution.